Data Issues and Cartographic Techniques as Applied to the Use of GIS in Epidemiology: The Alberta Health Model

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Abstract

Data used for spatial analysis of health research are available from several sources and in a variety of formats. Geographic boundaries used to define these datasets are not consistent, which results in problems with data presentation. A consistent and appropriate geographic segmentation of a region is necessary to reveal geographic patterns and ensure that their implied relationships are real and not a result of boundary placement. Cartographic literature provides limited assistance to the researcher attempting to manage these difficulties effectively. Inconsistencies in the literature and discussions of mapping technique limitations force the researcher to deal with these issues on a case-by-case basis. This paper outlines a variety of cartographic techniques and discusses methods of presenting spatial data used by Alberta Health, Surveillance Branch.

Keywords: mapping techniques, geographic boundaries, Alberta Health, Canada

Introduction

The mission of the Government of Alberta's Department of Health (Canada) is to protect, maintain, restore, and enhance the health of Albertans. To achieve this, the Surveillance Branch of Alberta Health is implementing geographic information systems (GIS). GIS enable researchers to examine health data from a spatial perspective. The use of GIS in epidemiology research has recently received much attention in research literature and from agencies responsible for the epidemiological research, and has been well documented by Clarke et al. (1). GIS can help researchers describe the spatial perspective of disease, but this must be done using a consistent spatial foundation.

Researchers at Alberta Health, Surveillance Branch, have examined the temporal-spatial patterns of health events and the possible determinants for these patterns. As a result of this work, researchers have become aware of the problems associated with data collection and issues of replication of results. The following sections outline the concerns related to geographic boundaries used in spatial analysis, and a method is presented to overcome data collection and replication concerns.

Health Data and Boundaries

The two main issues confronting GIS research as applied to epidemiology are inconsistent geographic boundaries and the size of mapping units. Locating and assigning

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individuals into geographic units is essential in the use of GIS in epidemiological research. Ideally, for spatial analysis, all individuals are linked to a fixed geographic location. The movement of individuals from this fixed location is tracked. (To ensure client confidentiality, the health data collected by an agency are only made available in an amalgamated format.) Aggregated data vary depending on how and why the data are collected. Boundaries assigned to geographic areas by research agencies are not consistent; therefore, the grouping of individuals into geographic units varies among agencies. For example, Statistics Canada uses census boundaries, while Alberta Health uses Regional Health Authority (RHA) boundaries.

Local spatial variations within a larger mapping unit are often masked due to data collection methods. For example, rural census subdivisions in the northern portion of the province are very large. Regional variations are expected within these areas, but the variations are not visible because information for the areas is amalgamated. The use of smaller data boundaries reduces this effect.

To examine the challenges associated with spatial analysis of health data in the Alberta context, it is necessary to consider the different kinds of boundaries Alberta Health could use in GIS research.

County

Counties are not as important in Canada as they are in the United States. The county is a logical spatial unit in the United States, but in Canada, health provision is organized according to other boundaries described below. It is quite difficult to obtain health data at the county level, so the county is not a recommended land unit for GIS use. Additionally, county boundaries in many provinces, including Alberta, are subject to change, as are their equivalents—municipal districts, improvement districts, special areas, etc.

Regional Health Authorities

The province of Alberta is divided into 17 RHAs. Spatial analysis of this geographic unit is relatively simple because most medical data are organized by RHA. RHA regions often encompass large areas, though; because regional differences within an RHA are not visible at this level of aggregation, detail is lost.

Census-Related Boundaries

Figure 1 shows four census-related boundaries—census divisions (CDs), consolidated census subdivisions (CCSDs), census subdivisions (CSDs), and enumeration areas (EAs)—and illustrates their hierarchy.

Census Divisions

CDs, as outlined by Statistics Canada, provide a level of aggregation similar to that of RHAs. As with RHAs, most needed medical data can be obtained at this level, but working at this level creates similar challenges to those encountered when using RHAs. CDs are suitable for census data (because they represent aggregations of the smaller census-related areas), but not for tracking health events.

Census Subdivisions

A division of the CDs into smaller units has resulted in the CSDs. The more than 400

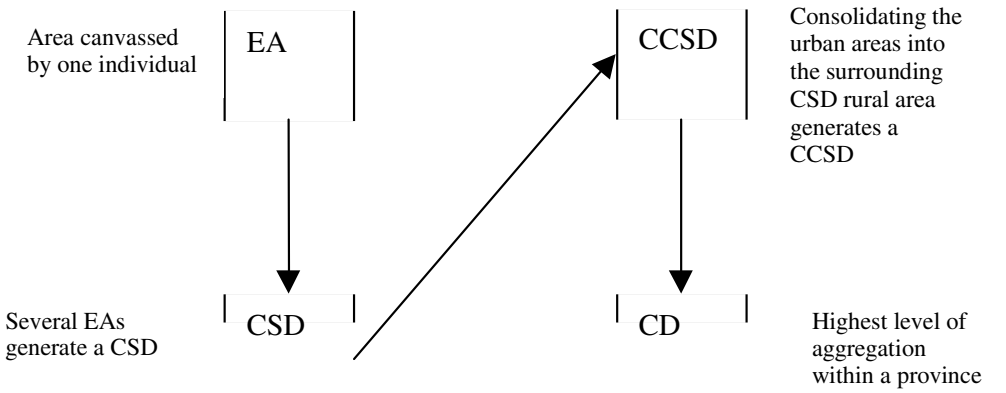

Figure 1 Summary of census boundaries.

CSDs in the province correspond to the municipal political boundaries, including counties, improvement districts, municipal districts, special areas, cities, towns, national parks, and reserves. Regional differences are more apparent when this level of aggregation is used. Unfortunately, many of the CSDs are very small and prove a challenge to cartographers who wish to use visual patterns to differentiate CSDs according to a health variable. If a pattern (e.g., crosshatching, shading) is applied to each CSD according to a health variable, many of the smaller units (such as towns or small cities) are not visible on a map of reasonable dimension. Many of these spatial units are not visible even when the page size for the map of the province is set to "E" size (34" by 44", the largest paper size most plotters can use).

Because CSDs represent legal entities, populations range from over 600,000 for the larger urban centers to under 100 for some native reserves and villages. It is difficult to create a comparable set of statistics for the entire province based on such variation. The larger urban centers cannot be subdivided to examine patterns in regions of the city; meanwhile, a single case can change the mortality or morbidity rate in a smaller community from a "No Cases" category to the highest category.

Consolidated Census Subdivisions

CCSDs, created by Statistics Canada, are amalgamations of CSDs. There are over 70 CCSDs in Alberta. Each consists of a rural envelope—counties, improvement districts, municipal districts, and special areas—and the amalgamation of all cities, towns, villages, and reserves within it. (All populations within a CCSD are added together to create larger populations and mapping regions.) Health data can be obtained at this level by using a CSD-to-CCSD lookup file and adding together all the necessary components. This level of detail is a good compromise between the RHA and CSD levels, especially when mapping incidence of rare diseases. CCSD boundaries make some regional variations evident, but some of the differences between urban and surrounding rural areas are lost.

Enumeration Areas

Each EA is an agglomeration of approximately 800 individuals, and represents the

region canvassed by a single census taker. Rural areas remain quite large when divided according to this scheme, especially in northern Alberta, where population densities are lower. Urban areas are subdivided into many smaller areas; the small size of these units makes this set of boundaries unsuited to traditional mapping techniques, although EAs are used to show detail in one small region. EA-level mapping is most often used for marketing, in which a city is divided into socioeconomic areas and categorized for potential sales. Many health data are not always available at the EA level, and therefore EA mapping is not recommended on a province-wide basis.

Postal Codes

Postal codes are also used to determine the location of a group of individuals. Locations of postal codes can be estimated as points. Medical data can be obtained at this level of aggregation because the mailing address of each Alberta resident is stored as part of Alberta Health's registration data. Postal code populations can be obtained from the same source. Some postal codes share the same geographic location because they are based at the same post office.

There are more postal codes in urban areas than in rural areas. This makes it possible to analyze regions of an urban center for differences. For example, an outbreak of giardiasis can be examined as it relates to the location of a specific water-processing plant. Such specificity is useful to an RHA or for a particular study that examines a disease or a geographic region in detail. The postal code technique is also useful in mapping rural areas. While rural areas defined as postal code regions may be large, they are smaller than rural areas defined by the previously described geographic boundaries.

Postal code areas are inferred using the locations of the post offices, but there are no digital files available that store the geographic boundaries for each postal code. When possible, overlapping postal codes are moved to create unique boundaries for each. The postal codes and populations are pooled together when moving these points is impossible. The urban areas—considered to be those regions served by a postal code *not* starting with "T0"—are examined at the 3-digit postal code (also known as forward sortation area) level. All data for these non-T0 postal codes are amalgamated, and the average geographic location is calculated. (There are some urban areas that are served by T0 postal codes, notably Drumheller and Rocky Mountain House.) The amalgamation of urban postal codes to 3 digits, in conjunction with all 6-digit rural postal codes, results in over 800 regions. Some rural postal codes may themselves be amalgamated to create geographic units with larger minimum populations. Amalgamations of rural and urban postal codes, as described, have been given the name "consolidated postal codes."

Findings

Based on these findings, the use of CSDs for health surveillance purposes is not recommended in the province of Alberta. Using RHA, CCSD, or CD boundaries results in large regions, in which local detail may not be visible. More importantly, the boundaries of all these regions change on a regular basis. Surveillance requires a consistent spatial base, so none of these boundaries are suitable.

Postal code data—and especially consolidated postal code data—are far better suited to this task in the province of Alberta because the numerator and denominator

are obtained from the stakeholders registration database.[1] The Personal Health Number (the number identifying each person in the database) is then used to link cases to this file. A constant geographic structure facilitates long-term surveillance research, but postal codes are always changing as old postal codes are retired and new ones are added. Disease surfaces created from these data may reflect changes that are the consequence of changes in postal codes, not significant changes in the data.

Clearly, an alternative method must be devised to enable researchers to effectively manage the problems described in this section (Table 1). Using latitude/longitude (lat/lon) blocks provides an innovative solution to these spatial issues.

Latitude/Longitude Blocks

Lat/lon blocks were devised in order to overcome the challenges associated with the

Table 1 Advantages and Disadvantages of Different Regional Boundary Types Used in GIS Analysis

Technique	Advantages	Disadvantages	Result
County	Similar unit used in the United States.	Data are not available at this level.	Not usable
Regional Health Authority (RHA)	Data are available at this level. Rates are somewhat stable. Decisions are made at the RHA level.	Boundaries change frequently. Regional differences within RHAs are not visible. Urban and rural data are mixed.	Used to report province-level data for public reports
Census division	Stable rates.	Boundaries change. Local variation not visible.	Not usable
Census subdivision	Population data are readily available. Regional differences are apparent. Data collection geography does not match these boundaries.	Stability of rates is questionable because large populations may be compared with small populations.	Not usable
Consolidated census subdivision	Data are readily available.	Difference between urban and rural communities is lost.	Limited use
Enumeration area	Smaller, more comparable populations.	Changes frequently. Size of EAs varies.	Not usable
Postal code	Data collection is based on these boundaries.	Changes frequently.	Limited use

[1] In Alberta, every person who wishes to receive health services must make monthly payments into the health plan. The stakeholders registration database exists to keep track of every person who makes these payments. The database also contains records of every health service; the action taken, diagnosis, etc., are assigned unique codes. For invoicing purposes, the database also contains a mailing address for each person who receives health services. The postal code information for each health event can be retrieved from this database.

techniques listed above. The northern, southern, and eastern boundaries of Alberta, as well as half of the western boundary, are formed by latitude and longitude lines (60° N, 49° N, 110° W, and 120° W, respectively). All political boundary lines are liable to change over time, but the framework that is used to describe their location (i.e., the geographic coordinate system) is not. This means that long-term surveillance can continue regardless of changes in boundaries.

Blocks based on the Universal Transverse Mercator (UTM) grid have been used to define consistent geographic regions to collect data. Many bird atlases use these blocks as a foundation, guaranteeing that any changes in the avian populations are real, not based on changes in boundaries. *The Atlas of Breeding Birds of Alberta* (2) and others have used this method. The challenge that arises with the use of UTM blocks is that blocks in which two UTM zones join become triangular, and therefore are not of the same size, meaning that populations may become too small. This may also present a cartographic problem: ensuring that the smaller blocks are visible.

Blocks generated using latitude and longitude lines may be a better choice for public health purposes. Although the blocks become smaller as latitude increases, these changes are predictable and measurable and are not as dramatic as those experienced with the UTM blocks. These lat/lon blocks can be set at any size, based on the population distribution characteristics of the region and also based on the number of cases associated with the health event under consideration.

The case and population structure information from each block's corresponding postal codes are used to amalgamate and display needed information. This ensures the protection of the confidential information. Because it creates blocks with larger populations, amalgamating information also makes it possible to calculate rates with more reliability and statistical confidence.

A number of diseases have been mapped using 1×2 lat/lon degree blocks—blocks of 1° latitude by 2° longitude. This technique is very effective because 1×2 lat/lon blocks are small enough to allow visual identification of regional patterns, but large enough to ensure large enough populations to allow accurate calculation of rates (Figure 2). Two-by-two (2×2) lat/lon degree blocks have been used to map diseases that affect smaller populations (Figure 3). Smaller grids (Figures 4 and 5) and variable-size grids (grids that are smaller in densely populated areas and larger in other areas) have been tested on some diseases, but the 1×2 and 2×2 grids are well suited for the province. It would be easy to use smaller grid units if necessary. It would also be easy to extend the same system to other regions. This method will be used in the pilot of a national surveillance system for Canada.

The method has also proven effective in mapping potential determinant data. Socioeconomic information is available from Statistics Canada, presented using any of the boundaries listed above. It is often difficult to examine data presented in a spatial format in context of health data that use other boundaries, but the EAs are small enough that the data can be aggregated to the same lat/lon blocks as the health data. The resulting maps can be readily compared at a glance (Figure 6). Environmental data are often more difficult to examine because the density of data collection can vary vastly from region to region. Data on each water well data in the province, for example, can be obtained from the provincial government, but in examining this information it is difficult to discern any patterns that may have an influence on human health. One solution to this problem is showing the total number of wells as a graduated circle, while

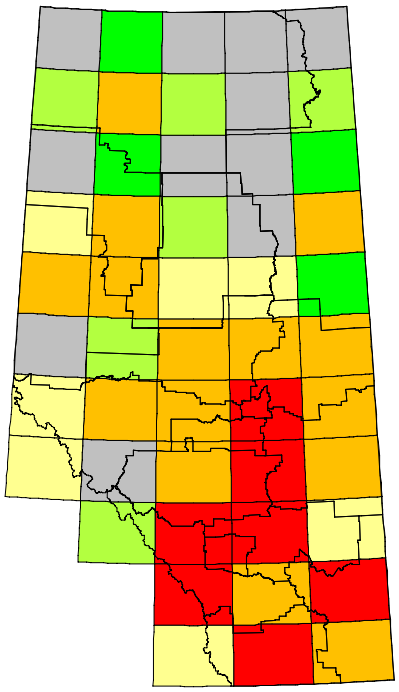

Figure 2 1×2 grid.

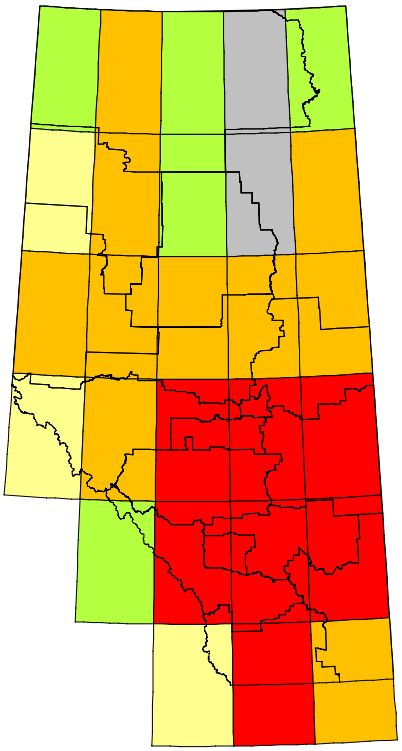

Figure 3 2×2 grid.

showing the proportion of wells that exceed national guidelines for a particular element as a pie sector (Figure 7). It is possible, then, to identify at a glance those areas that have large numbers of wells that exceed guidelines, and the reporting boundaries are identical to those used to map a potentially related health event. This method also makes it possible to ensure that confidentiality is maintained for health data as well as potential determinants.

The lat/lon blocks are an excellent vehicle for surveillance and for identifying regions in which a series of health events occur more often than is normal. The technique is not as well suited to analyzing smaller regional patterns. The size of the blocks can be decreased, but this can generate errors, because the allocation of a postal code to a block has greater repercussions when the population of each of these blocks is smaller. The small blocks will be very useful when health data can be obtained that are more precise than postal code-level data.

Conclusion

GIS is a useful tool within the field of epidemiology, but software and training costs often prevent successful implementation, as does access to base data. The researcher must be aware of the challenges associated with using various spatial units. The discussion above outlines a method developed at Alberta Health Surveillance for presenting and analyzing health and determinant data from a spatial perspective. This method

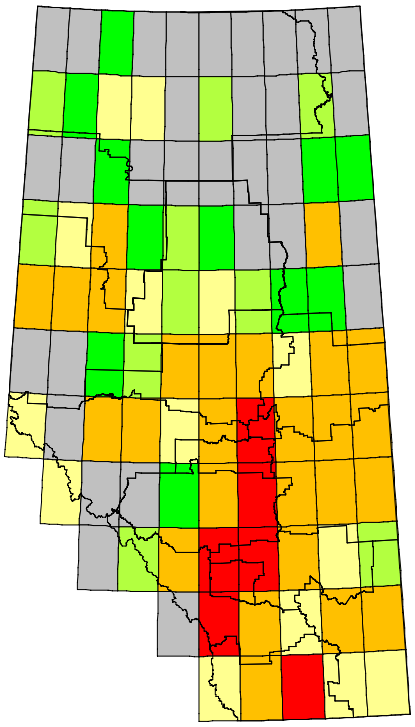

Figure 4 1×1 grid.

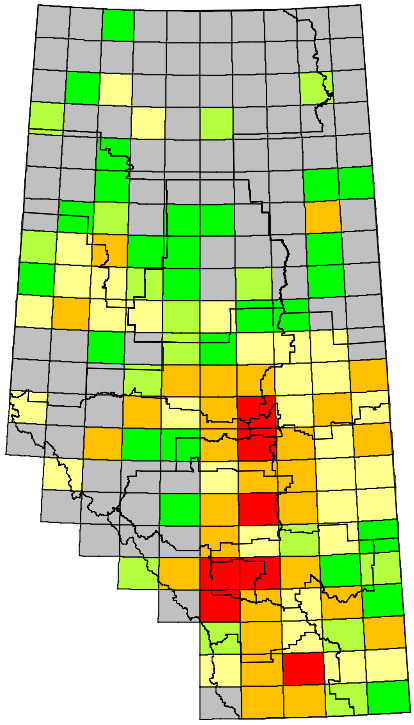

Figure 5 .5×1 grid.

is well suited to examining provincial data from a long-term surveillance effort. (The examination above of other possibly suitable boundaries provides a context for the creation of this method.)

The use of lat/lon blocks is recommended in jurisdictions where data to be compared are collected using different boundaries. The method is also well suited for jurisdictions in which limited budgets have not allowed the development of spatial health analysis, because much of the work can be performed without access to GIS tools. Block membership can be obtained from the lat/lon coordinates of any point; maps can be generated by filling in the colors in each block using the graphics editing capabilities of any current word processor; and the bubble chart option in many spreadsheet programs is able to generate simple pie chart maps.

The method demands few resources, provides a consistent geographic structure, simplifies comparisons among datasets collected by different agencies, and provides a means of examining issues that cross political boundaries. For these reasons, the use of the lat/lon block method is recommended.

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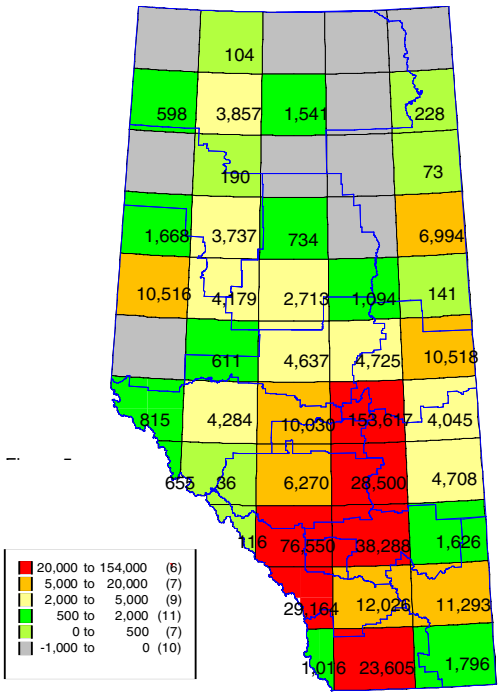

Figure 6 Socioeconomic data summarized to lat/lon block.

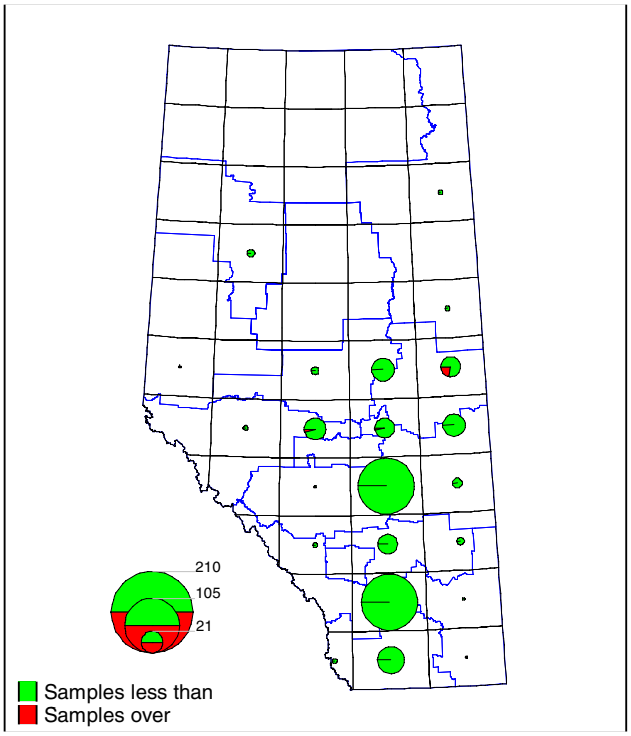

Figure 7 Water contamination summarized to lat/lon.